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Effects of mandibular setback surgery on upper airway dimensions and their influence on obstructive sleep apnoea – A systematic review

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ABSTRACT

Background: Mandibular setback used to be the traditional treatment of choice for correcting mandibular prognathism. Nowadays, bimaxillary surgery is preferred. Several authors have asserted that mandibular setback causes a relative narrowing of the upper airway (UA) that could trigger obstructive sleep apnoea (OSA); however, its potential role in OSA development is still much debated. Another controversial subject is whether changes in airway space caused by the procedure are permanent.
Objectives: To ascertain the consequences for UA size and shape of mandibular setback surgery in comparison with bimaxillary surgery (maxillary advancement with Le Fort I and mandibular setback), and to analyse the changes in oximetric indices and their relationship with OSA.
Search methods: A systematic review was made of the bibliography in 4 databases: Medline, Scopus, Embase and Cochrane.
Selection criteria: Systematic reviews, meta-analyses, clinical trials and cohort and case–control studies of adults published in the past 15 years were included.
Data collection and analysis: The initial search yielded 668 articles, of which 498 were eliminated because of duplication and 123 on the basis of their titles and abstracts or summaries. The remaining 47 papers were read in their entirety, and 14 were included in the final selection.
Results: According to our observations, the nasopharyngeal space does not undergo significant changes after either of the two surgical procedures. In the oropharynx and hypopharynx, none of the measurements changed significantly with maxillary advancement; however, persistent and significant decreases in the area, horizontal linear dimensions, and volume of these spaces are encountered after mandibular setback alone. No long-term changes in oximetric indices were found.
Conclusions: Morphological changes are more pronounced following exclusively mandibular surgery. A decrease in the UA does take place but appears not to affect the patient's sleep quality. This study found no evidence to confirm that bimaxillary or mandibular orthognathic surgery predisposes to obstructive sleep apnoea development.

1. Introduction

Traditionally, the surgical procedure of choice to correct mandibular prognathism has been mandibular setback (Kawamata et al., 2000), but nowadays this is used in only 10% of cases (Degerliyurt et al., 2009). Some authors have indicated that it leads to a relative narrowing of the upper airway (UA) (Turnbull and Battagel, 2000; Foltán et al., 2009; Mattos et al., 2011; Gokce et al., 2012). The preferred choice currently is bimaxillary surgery

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(Gokce et al., 2012), as it achieves a better aesthetic effect and the airway anatomy is affected to a lesser degree (Park et al., 2012; Lee et al., 2013; Gonçales et al., 2014; Lee et al., 2012). Narrowing of the airway is expected after mandibular setback, and some authors have pointed to this as a factor triggering obstructive sleep apnoea (OSA) (Park et al., 2010). However, the potential role of this narrowing in OSA development remains a much-debated subject (Demetriades et al., 2010). It must not be forgotten that a physiological postural response to prevent airway collapse takes place after this surgery (Gokce et al., 2012; Panou et al., 2013; Kawamata et al., 2000; Jakobsone et al., 2010). Other controversial questions are whether the changes in the airway brought about by the surgery are permanent (Kim et al., 2013a; Park et al., 2010) and whether they also affect skeletal stability (Gonçales et al., 2014; Park et al., 2012).

The objectives of this review are to ascertain the consequences for UA size and shape of mandibular setback surgery in comparison with bimaxillary surgery (maxillary advancement with Le Fort I and mandibular setback), and to analyse the changes in oximetric indices and their relationship with OSA.

2. Materials and methods

The bibliography on UA alteration by mandibular setback and bimaxillary surgery (maxillary advancement with Le Fort I and mandibular setback) was subjected to a systematic review. It was carried out by two independent reviewers who followed the CONSORT criteria (Schulz et al., 2010). The 4 data bases searched were Medline, Scopus, Embase, and Cochrane. The search was made and updated on 15 April 2014. The following search limitations were set: type of publication: articles, articles in press and reviews; studies of adults; type of study: systematic reviews and meta-analyses, clinical trials, cohort studies, and case–control studies; publication date in the past 15 years. The search strategy used a combination of 5 primary MESH terms related to orthognathic surgery and 9 secondary terms referring to the upper airway. The terms were as follows, and all of the possible combinations between them were explored: 'orthognathic surgery', 'mandibular setback', 'bimaxillary surgery', 'malocclusion, Angle class III', 'prognathism', 'airway', 'posterior airway space', 'PAS', 'pharyngeal space', 'pharynx', 'nasopharynx', 'oropharynx', 'hypopharynx' and 'hyoid bone'.

The initial search yielded 668 articles, of which 498 were duplicate references. Of the remaining 170, an initial selection based on their titles and abstracts or summaries eliminated a further 123 articles. The remaining 47 papers were read in their entirety and 14 were selected for analysis: 12 retrospective and 2 prospective studies (Fig. 1). Of the 14 included, 8 were based on three-dimensional imaging techniques to record morphological and volume changes in the airway, and six analysed postoperative ventilation. Within the first of these two groups, six collected information on changes following bimaxillary surgery and five on changes following mandibular setback surgery. In the second group, four studied bimaxillary surgery and four addressed setback surgery.

To control the selection bias, two independent reviewers evaluated the titles and abstracts selected. Duplicate references were removed. The differences between both reviewers were solved by consensus.

The variables chosen for comparison between the studies were demographic (gender and age), sample size, type of surgery, follow-up time, technical parameters concerning the CBCT/CT apparatus

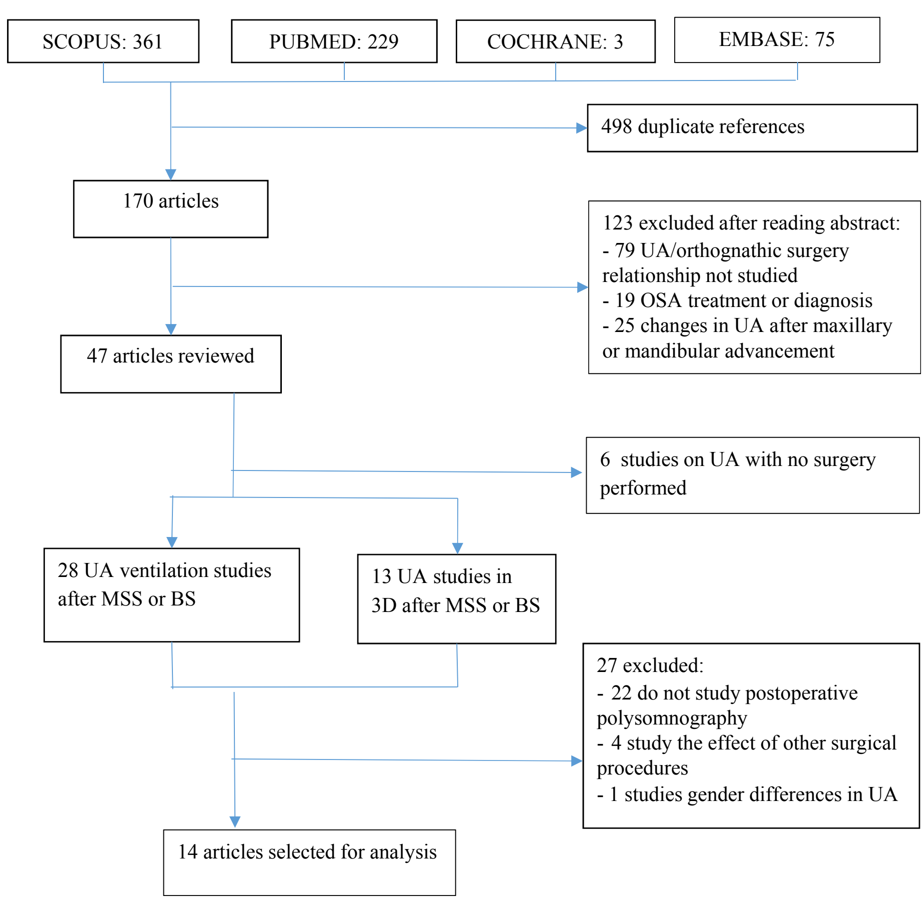

Fig. 1. Flow diagram.

Table 1
Variables in 3D and ventilation studies.

Authors, year	Type of study (R/P)	*n*	Gender (M/F), age	Type of procedure	Follow-up time (T0 = pre-op)	Article quality
3D studies						
Degerliyurt et al., 2008	R	47	13/34 23.3 ± 6.3	- 24 MSS - 23 BS	T1: 3 m post-op	Moderate
Gonçales et al., 2014	R	9	24.83	- 9 BS	48.28 d post-op	Moderate
Hong et al., 2011b	R	21	14/7 22.6 ± 4.21	- 12 MSS - 9 BS	T1: 2 m post-op	High
Jakobsone et al., 2010	P	14	8/6 20.3 ± 2.0	- BS	T1: 6 m post-op	Moderate
Lee et al., 2012	R	21	6/15 22.7	- BS	T1: 1 d post-op T2: 3 m post-op T3: 6 m post-op	High
Lee et al., 2013	R	24	21/26 19–32	- MSS	T1: 6 m post-op	Moderate
Park et al., 2010	R	12	5/7 25.5	- MSS	T1: 6 m post-op	Moderate
Park et al., 2012	R	36	23/13 22.97 ± 3.01	- 20 MSS - 16 BS	T1:4.6 m post-op T2: 1.4 y post-op	Moderate
Ventilation studies						
Demetriades et al., 2010	R	26	–	- MSS - BS	T1: post-op (Not specified)	Moderate
Foltán et al., 2009	R	21	7/14 20.67 ± 3.51	- BS	T1: post-op (Not specified)	Moderate
Gokce et al., 2012	R	21	21/0	- BS	T1: >1 y post-op	High
Hasebe et al., 2011	R	22	8/14 22	- 11 MSS - 11 BS	T1: 6 m post-op	Moderate
Kitagawara et al., 2008	R	17	5/12 21	- MSS	T1–2: 3–7 d post-op T3–4: 1–6 m post-op	Moderate
Kobayashi et al., 2013	R	78	29/49 24	- 21 MSS - 57 BS	T1-2-3-4: 1-3-5-7 d post-op T5: 6 m post-op	Moderate

Study quality: according to CONSORT criteria (Schulz et al., 2010). R/P = Retrospective/Prospective, N = sample size, M/F = male/female, d = days, w = weeks, m = months, y = years, pre-op = preoperative, post-op = postoperative, BS = bimaxillary surgery, MSS = mandibular setback surgery.

and scan conditions, and airway reference planes (Table 1). The protocols used in the scans were also examined to ensure that variations between them did not alter the results. Finally, the articles were classified as being of high, medium, or low quality according to the CONSORT criteria (Schulz et al., 2010): 11 were of medium quality and three of high quality.

3. Results

3.1. Characteristics of the imaging studies and of the measurements

Each of the studies refers to different anatomical planes in the upper airway. The eight studies recognise nine anatomical landmarks from which to construct planes at different levels of the UA (Table 2). The area, antero-posterior, and lateral dimensions and volume are measured on these planes, forming an image of the spatial morphology of the airway.

3.2. Results following bimaxillary surgery (BS)

The changes observed with bimaxillary surgery are less noticeable than with mandibular surgery. As regards the area measurements, no significant changes are found on the plane running from the posterior nasal spine to the posterior point of the ala of the vomer (PNS-Vp) (Park et al., 2012) or on the horizontal plane running through the posterior nasal spine (PNS) (Gonçales et al., 2014; Hong et al., 2011b). A slight increase in the area was observed at 2 and 5 months but diminished over time.

On the horizontal plane running through the first cervical vertebra (C1), there is less agreement of the findings. Two studies found very small, nonsignificant variations (Degerliyurt et al., 2008; Jakobsone et al., 2010). However, the study by Park et al. (2012) found a significant increase in the first 5 months, which later diminished but was still greater than at T0 after 1.4 years. The anterior–posterior dimension of this same section was definitely affected, although Lee et al. (2012) did not consider this clinically relevant because the variation was very small. With regard to the planar areas and linear dimensions from C1 to the last plane studied, which passes through the fourth cervical vertebra (C4), no further significant change was observed (Degerliyurt et al., 2008; Hong et al., 2011b; Park et al., 2012) except for a decrease in the area at C4 that persisted in the long term. Some authors have also found a significant decrease in the anterior–posterior dimension at the level of the first three cervical vertebrae (C1, C2, and C3), although this was not borne out by all of the studies (Degerliyurt et al., 2008; Lee et al., 2012; Park et al., 2012).

At the tips of the uvula and epiglottis and in the vallecula, the measurements remained unchanged (Gonçales et al., 2014; Hong et al., 2011b; Jakobsone et al., 2010).

Table 2
Planes on which the linear dimensions are measured.

Authors, year	Plane landmarks
Lee et al., 2013 Lee et al., 2012 Park et al., 2012 Jakobsone et al., 2010 Park et al., 2010 Degerliyurt et al., 2008	Antero-inferior point of the first four cervical vertebrae (C1, C2, C3, C4), parallel to the Frankfurt plane
Gonçales et al., 2014 Hong et al., 2011b Park et al., 2010	Posterior nasal spine (PNS), parallel to the Frankfurt plane
Lee et al., 2013 Park et al., 2012	Posterior nasal spine (PNS) to posterior point of the ala of the vomer (Vp)
Gonçales et al., 2014 Hong et al., 2011b	Tip of the uvula, parallel to the Frankfurt plane
Jakobsone et al., 2010	Tip of the epiglottis
Gonçales et al., 2014 Hong et al., 2011b	Base of the epiglottis or vallecula, parallel to the Frankfurt plane

The total UA volume was smaller following bimaxillary surgery in two of the studies in which this measurement was taken (Hong et al., 2011b; Lee et al., 2012), but the decrease was only statistically significant in one study (Hong et al., 2011b). In contrast, Jakobsone et al. (2010) found an increase in UA volume 6 months after surgery.

By region, the nasopharynx remains unchanged, whereas the oropharynx and hypopharynx were smaller after 5 and 6 months but recovered over the long term (Jakobsone et al., 2010; Park et al., 2012).

3.3. Results following mandibular setback surgery (MSS)

As with the results following maxillary surgery, no significant changes in planar area were found on PNS-Vp or on the horizontal plane at the PNS (Hong et al., 2011b; Lee et al., 2013; Park et al., 2012). At the levels of the uvular tip and the base of the epiglottis, the planar area and anterior–posterior dimension decreased (Hong et al., 2011b). At the C1 level, all of the studies agreed in finding a decrease in planar area and in antero-posterior and lateral measurements (Degerliyurt et al., 2008; Lee et al., 2013; Park et al., 2012). Park et al. (2012) show a repeated pattern of significant and progressive decrease in the area from T0 to T2 at C2, C3, and C4 which is supported by other studies (Degerliyurt et al., 2008; Lee et al., 2013; Park et al., 2010). These same authors agree that the linear dimensions decrease on all four horizontal planes through the cervical vertebrae. Finally, the total volume decreased in all of the studies (Hong et al., 2011b; Park et al., 2010, 2012). Park et al. (2010) did not report the changes as being significant, either in total volume or when divided into regions. However, Park et al. (2012) found that the total decrease was relevant and continued 1.4 years after surgery. The nasopharynx did not change, but there was a significant decrease in oropharyngeal and hypopharyngeal space (Lee et al., 2013; Park et al., 2012). According to Park et al. (2012), the differences were significant for T1/T2-T0 in the oropharynx and for T1-T0 in the hypopharynx.

3.4. Changes in respiratory parameters

Postoperative changes in the oximetric indices measured by nocturnal polysomnography or pulse oximetry show a relationship with clinical OSA in arterial oxygen saturation (SpO_2), the O_2 desaturation index (ODI), CT90, and the apnoea/hypopnoea index (AHI). Hasebe et al. (2011) and Kobayashi et al. (2013) agree that the variations in CT90 and ODI are not significant in the long term. There is disagreement with regard to arterial oxygen saturation, however. According to Hasebe et al. (2011), the SpO_2 tended to rise, but in Foltán et al. (2009) it decreased significantly, and Kobayashi et al. (2013) found that despite a decrease on postoperative day 1, the level gradually rose and had returned to normal after 6 months.

In the articles included in this review, the changes in the apnoea/hypopnoea index are not significant (Foltán et al., 2009; Hasebe et al., 2011). Following mandibular setback surgery, SpO_2, ODI, and CT90 present no significant changes in the medium term (6 months) (Hasebe et al., 2011; Kitagawara et al., 2008; Kobayashi et al., 2013). The immediately postoperative evolution shows a worsening in the first week, but over time the indices recover to practically T0 levels (Hasebe et al., 2011; Kawamata et al., 2000). The apnoea/hypopnoea index shows no significant changes either (Hasebe et al., 2011). In addition, a questionnaire that asked the patients whether they had noticed a greater tendency to snoring following this procedure did not yield significant differences (Kitagawara et al., 2008).

4. Discussion

The evidence collected on morphological and volumetric changes in the airway following orthognathic surgery is scarce. The rigorous screening of methodologically acceptable articles undertaken for this systematic review had consequences for the number of articles included. In addition, different anatomical planes were used in each of the studies, causing difficulties in compiling and comparing the results.

4.1. Changes in linear and area measurements following bimaxillary surgery (BS)

Plane-by-plane analysis of morphological changes following bimaxillary surgery yielded few significant changes. At C1, the airway area increased in the first months (T1) but fell after 1.4 years (T2), although it was still greater than at T0 (Park et al., 2012). The gradual decrease between T1 and T2 could be due to adaptive physiological changes whereby the soft palate repositioned itself rearwards to maintain correct palatal function and to preserve the oropharyngeal seal (Jakobsone et al., 2010; Turnbull and Battagel., 2000). As regards linear dimensions, significant changes were generally slight (Degerliyurt et al., 2008; Lee et al., 2012; Park et al., 2012). As no significant lateral changes have been reported, the effect can be considered largely anterior–posterior.

4.2. Changes in linear and area measurements following mandibular setback surgery (MSS)

The most significant difference between the two surgical procedures lies in the planar area. Following bimaxillary surgery, this remained practically unchanged, but following setback surgery alone, all of the papers analysed confirmed a decrease, which was also found in the linear dimensions (Degerliyurt et al., 2008; Lee et al., 2013; Park et al., 2010). On the four planes studied by Park et al. (2012) (C1, C2, C3, VC4), the decrease in area not only persisted in the long term but was also progressive, since at T2 it was even greater than at T1. Despite the findings reported, it cannot be concluded that these changes are permanent, as no longitudinal studies with long-term follow up of the patients were encountered. According to these results, the long-term postoperative evolution following mandibular surgery does not appear to be influenced by physiological adaptation, as there seems to be no recovery of the previous values (Lee et al., 2013; Park et al., 2012, 2010; Hong et al., 2011b; Degerliyurt et al., 2008). It may be that, in these cases, recovery is lengthier because the initial change is greater. The amount of mandibular setback could also influence the results, as it can be assumed to be greater when this procedure is not combined with maxillary advancement (Kim et al., 2013b; Park et al., 2012).

4.3. Volumetric changes

Comparison of the air volumes reported is highly questionable, as each author group defines different limits. It is possible only to compare a postoperative tendency to widening or narrowing. As regards total volume, there is disagreement on the results of bimaxillary surgery. Two studies found that it decreased (Hong et al., 2011b; Lee et al., 2012) and one that it increased (Jakobsone et al., 2010). According to Jakobsone et al. (2010), these differences could be the result of using different airway segmentation methods. With mandibular setback surgery alone, all of the authors confirm a decrease in total airway volume (Park et al., 2012, 2010; Hong et al., 2011b).

By UA region, the nasopharynx remains unchanged in both surgical procedures, whereas the oropharynx and hypopharynx

are reduced. Following bimaxillary surgery, the values do not remain constant over the long term, which fits the theory of physiological adaptation of the structures (Panou et al., 2013; Gokce et al., 2012; Demetriades et al., 2010; Degerliyurt et al., 2008). According to Park et al. (2012), following mandibular surgery there is a greater decrease in oropharyngeal volume, possibly because this posterior airway zone is the one closest to the mandible and the tongue.

4.4. Study limitations

To be certain of the changes that take place after orthognathic surgery, long-term follow-up is required, but the study by Park et al. (2012) is the only study included in this review that assessed the three-dimensional changes in the airway for more than a year.

Some studies lack information on the radiography method used, which influences the images obtained and, consequently, the results. The majority of studies are retrospective, and the authors therefore often had no control over the technique (Turnbull and Battagel., 2000). The review by Guijarro-Martínez and Swennen (2011) sets out the parameters that need to be taken into account for a CBCT or CT in the oromaxillofacial region. The most important of these are the patient's position (vertical or supine) and head position during examination, as they entail changes in the adjacent structures that, in turn, affect the pharyngeal dimensions (Guijarro-Martínez and Swennen, 2011; Kim et al., 2013b; Mattos et al., 2011) It is important to know which airway segmentation method is used, and also the scanning time, as this influences respiration phase control.

4.5. Changes in respiratory parameters

Ventilation was not affected by either of the two procedures (Kobayashi et al., 2013; Hasebe et al., 2011; Foltán et al., 2009; Kitagawara et al., 2008). Following bimaxillary surgery, there were changes in AHI, ODI, and CT90, but the respiratory functions were unaffected in the long term (Foltán et al., 2009; Hasebe et al., 2011; Kobayashi et al., 2013). The disagreement concerning SpO_2 is due to the differing follow-up times, showing that the worsening occurred in the short term (Foltán et al., 2009). Following mandibular setback alone, the respiratory functions also remained steady in the long term. As with the bimaxillary procedure, ODI, CT90, SpO_2, and AHI were modified in the short term, showing a worsening of the respiratory functions, but had recovered at the 6-month point (Hasebe et al., 2011; Kitagawara et al., 2008; Kobayashi et al., 2013). Various studies observed a positive correlation between the rise in the number of apnoea and hypopnoea events and the body mass index (Enciso et al., 2010), and also between apnoea/hypopnoea and the amount of mandibular setback (Demetriades et al., 2010; Hasebe et al., 2011; Kobayashi et al., 2013). For this reason, several authors conclude their articles with the warning that particular care should be taken with obese patients and with those who undergo considerable mandibular setback (Kitagawara et al., 2008).

4.6. Recommendations for future studies

The greatest difficulty encountered in this review lay in the heterogeneity of the methods reported in the different articles. It would be useful to follow a standard protocol for CBCT imaging and use standard reference planes. It would also be desirable to conduct long-term follow-up studies of changes in the airway and find out whether, in the long term, adaptation of the soft tissues reverses these changes caused by orthognathic surgery.

5. Conclusions

Based on our study findings, we conclude the following:

- In the medium term, the only significant change in UA morphology following bimaxillary surgery is an increase in horizontal area on the plane passing through the first cervical vertebra (C1) and a decrease in horizontal area on the plane passing through the fourth vertebra (C4).
- After mandibular setback surgery alone, there is a significant decrease in area in the UA in general that persists in the medium and long term.
- Comparison of the volume shows that it is highly variable. Only the results after mandibular setback alone are consistent in all of the studies. In this case, the total volume decreases, as does that of the oropharynx and hypopharynx, although the nasopharynx does not vary. The author groups differ over volume changes following bimaxillary surgery.
- The postoperative findings for arterial oxygen saturation, the O_2 desaturation index, CT90, and the apnoea/hypopnoea index show no long-term changes in ventilation. Consequently, there is no evidence to confirm that bimaxillary or mandibular orthognathic surgery predisposes to obstructive sleep apnoea development.

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